Content information layer for an optical record carrier

The present invention relates to a content information layer for an optical record carrier, to a method of manufacturing a record carrier including such an information layer, and to associated methods and devices for embedding content information within the layer. The layer is particularly suitable for, but not limited to, application on two-sided optical discs.

Optical discs are information storage discs that can be read by scanning the disc with a beam of radiation, normally of a predetermined wavelength. The term radiation is understood to mean not only radiation in the visible part of the spectrum, but radiation of all wavelengths of electromagnetic radiation.

Current optical discs exist in a number of formats, including CD (Compact Disc), DVD (Digital Versatile Disc) and BD (Blu-ray Disc). Figure 1 shows an example of a typical optical disc 100. The disc is formed in a number of layers (103, 104, 105, 107). A user information layer 104 stores information upon the disc 100, and is read by a beam of radiation incident upon the entrance face 106. The user information layer is typically covered by a cover layer 103, with a substrate layer 105 providing mechanical support and/or protecting the user information layer 104 from environmental influences. In order to allow a user to identify the disc from other, similar discs, a content information layer 107, also called a label, is provided on the surface of the disc opposite to the entrance face 106. The content information or label information is user visible, i.e. generally legible and interpretable by the user using the naked eye. The content information is represented by or encoded in zones which reflect or absorb incident ambient light in a way different from the medium surrounding the zones. A zone may consist of a dye having a different color than the surrounding medium. A single zone may form a pattern; a plurality of zones may also form one or more patterns, e.g. characters and images. The content information typically provides information on the content of the user information layer and the type of the disc. It may contain a range of relevant information for the user, such as the type of record carrier (e.g. CD, DVD, CD-R, CD-RW), the name and track list of a music disc, or the description of the software for a computer program distribution disc.

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In order to increase the storage capacity of an optical disc, it is desirable to use both sides of the disc to store user information i.e. to have a two-sided disc. However, it is then not possible to provide a normal user visible content information layer or label on the disc, as such a reflecting/absorbing layer would interfere with the scanning of the user information layer on that side of the disc. If no content information layer is provided, then identification of the disc becomes problematic.

It is an aim of embodiments of the present invention to provide an improved content information layer which addresses one or more of the problems of the prior art, whether referred to herein or otherwise.

It is aim of particular embodiments of the present invention to provide a content information layer that may be applied to a two-sided optical record carrier and does not prevent the scanning of the information on both sides of the record carrier.

In a first aspect, the present invention provides an optical record carrier comprising at least one content information layer and at least one user information layer arranged to be scanned through the content information layer by first radiation; the content information layer comprising at least one zone representing content information in a surrounding medium, the content layer being transparent for said first radiation and the zone and surrounding medium providing an optical, visual contrast for a different, second radiation.

The content information layer, both the at least one zone and the medium surrounding it, should be transparent for the first radiation, used for scanning the user information layer of the record carrier. The transmission for first radiation is preferably so high, that writing, reading and/or erasing of the user information layer is not affected by the presence of the content information layer.

The single-pass transmission of the layer for the first radiation is preferably more than 70% more preferably more than 90% for record carriers on which a user can record user information. The transmission of the zone and of its surrounding material for the first radiation is preferably substantially equal, i.e. equal within 10% or more preferably 3%.

The zone and its surrounding medium show an optical contrast at a second radiation, different from the first radiation. The second radiation is used for viewing the content information. The contrast is preferably sufficient for the unaided eye to read the content information. A contrast of 4% or more is in general sufficient for observation by the unaided eye. For improved visibility a contrast of 30% or more is preferred. The contrast relates to the second radiation. Where the second radiation comprises a small or large

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wavelength range, the contrast relates to this respective small or large range. For example, a higher reflection of a zone compared to its surroundings in the red part of the spectrum should have the above minimum contrast in this red part, causing the zone to appear red to an observer.

The contrast between the zone and its surrounding medium may be in the form of e.g. a different color, a different type of reflection such a specular and diffuse reflection, or a different amount of reflected radiation. The second radiation is in general one or more components of the ambient light, preferably in the visible part of the spectrum. The desired contrast should be achieved for at least one component of the second radiation within the visible spectrum.

By providing such a content information layer, the at least one zone allows the unimpeded transmission of the first radiation used to scan the user information layer. However, under irradiation with second radiation, such as ambient light, the zone will be visible to the user, as it will reflect and/or absorb at least part of the incident radiation. Thus a content information layer in which the content information is recorded in such zones does not interfere with the scanning of the user information in the user information layer. Consequently, such a content information layer may be arranged in or on a two-sided optical record carrier to provide content information about the record carrier.

In a preferred embodiment the at least one zone has a first transmission for said first radiation and a second, lower transmission for a different, second radiation. The lower transmission for the second radiation may be caused by an larger absorption or reflection of the zone. The second transmission is preferably so much lower than the first transmission, that the zone will absorb or reflect a substantial amount of incident radiation, causing sufficient contrast to be visible under ambient lighting conditions.

In a special embodiment the content information layer has a high transmission for first radiation having a predetermined polarization and provides an optical contrast for second radiation having a different polarization. The first radiation may e.g. be linearly polarized and the second radiation is linearly polarized in a direction perpendicular to the direction of polarization of the first radiation. The second radiation may be one or more components of ambient light that have the mentioned linear polarization. A zone in the content information layer may be made of a material having a dependent-dependent transmission, preferably a birefringent material; the medium surrounding the zone being non-birefringent. When the birefringent material is properly oriented, the incident first radiation will not experience changes of refractive index in passing the zone and the surrounding

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medium. In contrast, the second radiation will experience refractive index changes on passing the zone, thereby reflecting part of the incident second radiation. The second radiation will not experience refractive index changes in passing the surrounding medium. The difference in reflection of second radiation between the zone and its surrounding medium causes an optical contrast that allows reading the content information stored in the layer. The transmission of the zone and the surrounding medium for the first radiation may be up to 100%. The transmission of a zone for the second radiation may be about 95% for a zone formed by a single birefringent volume; the transmission can be as low as 9% for a zone formed by a plurality of birefringent particles dispersed in a matrix material. The particles diffusely reflect incident second radiation by multiple reflection and refraction. The matrix material may be isotropic or anisotropic.

In another special embodiment the content information layer has a high transmission for first radiation having a predetermined wavelength and provides an optical contrast for second radiation having a different wavelength. The wavelength of the first radiation may be the wavelength of the laser used for scanning the record carrier. The second radiation may be one or more components of ambient light that have a different wavelength. A zone in the content information layer may be made of a material having a wavelength-dependent transmission; the medium surrounding the zone is made of a material having a different wavelength dependence of its transmission. Both materials may be dyes. The zone may be made of dye only or dye embedded in a matrix. The medium surrounding the zone may be made of the same material as the matrix. The transmission of the zone and its surrounding medium at the wavelength of the first radiation will be high. The reflection of the second radiation in a zone will be different from the reflection in the surrounding medium, thereby providing the desired optical contrast. The transmission of the zone and the surrounding medium for the first radiation may be more than 90% and may be close to 100%. The reflection of a zone for the second radiation may have any value between 0 and 100%, the reflection of the surrounding medium may also have any, different, value in this range. The contrast caused by the difference in reflection should be achieved for at least one wavelength in the visible part of the spectrum. The transmission of a may be between 100% at the wavelength of the first radiation and down to 0% at another wavelength. If for example a zone has a high reflection around 600 nm and a low reflection at other wavelengths and the surrounding medium has a low reflection at all wavelengths in the visible part of the spectrum, the zones will appear red in a light background.

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The content information layer may comprise the same material for both the zones and their surroundings, but the optical properties of the material in the zone have been made different from that in the surroundings. The optical properties may be the wavelength-dependence or the dependence-dependence of the transmission. For example, the material comprises birefringent particles dispersed in an isotropic matrix. The orientation of the birefringence of the particles in the zones is chosen differently from the orientation of the birefringence of the particles in the surroundings, in such a way that radiation having the first polarization experiences the same refractive index in the matrix and in the particles, both in the zones and in their surroundings, and that radiation having the second polarization experiences different refractive indices in the matrix and in the particles which are within in a zone and the same refractive index in the matrix and the particles which are in the surroundings.

In another embodiment the content information layer has an area and comprises a plurality of substantially equally spaced and substantially opaque colored subareas. The wording colored includes black, grey and white. The subareas, e.g. colored ink dots, are deposited onto the surface of the substrate of the optical record carrier. An optical record carrier reading or writing device is usually tested for robustness against fingerprint sensitivity by deliberately putting ink dots on the substrate surface. Since the optical beam, i.e. the first radiation beam, at the surface of the substrate has a substantial width, small ink dots will not hinder the writing and read out of information from the deeper user information layer. It is therefore preferred that said colored subareas have a size between 75 and 20000 $\mu m^2$. The last figure corresponds to subarea with a diameter of approximately maximally 150 μm. Preferably the diameter is smaller than 50 μm. In order to assure optical sufficient transmission for the first radiation said colored subareas occupy a value selected from 10 to 30 % of the total the content information layer area and are substantially evenly spread over the total the content information layer area. By having an even spread sudden transmission changes are avoided. A critical part of a semi-transparent label is avoiding sudden transmission changes between borderlines of the visual pattern of the label. By using substantially opaque subareas these transmission changes are virtually absent. Visually sharp edges may be achieved by using a different ink color for the subareas while keeping the same areal coverage. For the optical record carrier reading or writing device only the unoccupied record carrier surface is of importance for the signal level. However dots may appear as sources of light scattering, but this scattering will not disturb the read out or write process because it is substantially out of focus. Slightly transparent subareas, e.g. dots, are not

excluded and in this case it is preferred to create "soft" edges of the visual label information by e.g. gradually decreasing the dot size or dot density at the edges.

In yet another embodiment the content information layer comprises a plurality of differently colored sublayers substantially equally transparent for the first radiation. E.g. thin homogeneous dye layers or coatings, which are transparent at the read-out or write wavelength are used. The dye areas preferably show few border lines between dye-non_dye or dye1-dye2 in the read-out or write zone. These dye areas not only must be substantially transparent but must also be substantially equal in transparency for the first radiation, e.g. the read-out or write wavelength of the optical record carrier reading or writing device. Preferably a homogeneous optically transparent dye is used and not a dye comprising small colored particles, i.e. an emulsion. Furthermore it is advantageous when the content information layer has a substantially uniform optical thickness at the first radiation wavelength in order to minimize disturbance of the optical wavefront of the focused radiation beam during reading and writing of information from or onto the user information layer of the optical record carrier at the first radiation wavelength. This may be achieved when the content information layer further comprises a substantially optically transparent and flat cover layer facing away from the at least one user information layer. In this way physical thickness variations and gaps between the sublayers are filled up and optical thickness variations are reduced.

In yet another embodiment the content information layer comprises dielectric layers having antireflective properties at the first radiation wavelength, which dielectric layers represent the visible content information. E.g. use dielectric coats, similar to the ones put on e.g. sun glasses to coat the label side fully or partially according to the desired label design. Such coats typically have a total thickness of a few ¼ wavelengths. Again few border lines between different colors are preferred. Again good transparency for the read-out or write wavelength is necessary.

The optical record carrier may combine two or more of the following properties: the material of the content information layer may be birefringent, dispersed in a matrix material, the material may be a dye, the zones in the content information layer may be patterned, the record carrier may be two-sided, at least one side having a content information layer and each side having a user information layer.

In another aspect the present invention provides an optical record carrier comprising at least one content information layer and at least one user information layer arranged to be scanned through the content information layer by first radiation; the content

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information layer comprising a material recordable to a pattern providing at least one zone representing content information in a surrounding medium, the content layer being transparent for said first radiation and the zone and surrounding medium providing an optical contrast for a different, second radiation.

In such a record carrier the presence and position of at least one zone in the content information layer can be changed under external influence, such as irradiation or electric field. Such a record carrier allows content information to be recorded in an unrecorded or partially recorded content information layer. It also allows to change the content information by erasing old content information and/or writing new content information.

Where the material of the zones is birefringent, the process of recording may involve locally changing the orientation of the birefringence, which, in the case of liquid crystal material, involves changing the orientation of the liquid crystal molecules.

In a further aspect, the present invention provides a device for writing content information to a content information layer on an optical record carrier, the optical record carrier comprising: at least one content information layer and at least one user information layer arranged to be scanned through the content information layer by first radiation, the content information layer comprising recordable material; the device being arranged to record said material of the content information layer so as to provide at least one zone pattern-wise representing the content information, the zone and its surrounding medium providing an optical contrast for a different, second radiation.

In another aspect, the present invention provides a method of writing content information to an optical record carrier, the optical record carrier comprising: at least one content information layer and at least one user information layer arranged to be scanned through the content information layer by first radiation, the content information layer comprising recordable material;
the method comprising the step of recording said material of the content information layer so as to provide at least one zone representing the content information, the zone and its surrounding medium providing an optical contrast for a different, second radiation.

In a further aspect, the present invention provides a method of manufacturing an optical record carrier, the method comprising: providing at least one user information layer arranged to be scanned by first radiation; and providing at least one content information layer comprising or recordable to provide at least one zone representing content information,

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the zone and its surrounding medium providing an optical contrast for a different, second radiation.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Fig. 1 shows a cross-sectional view of a single sided optical disc;

Fig. 2 shows a cross-sectional view of a two-sided disc incorporating a content information layer in accordance with a first embodiment of the present invention;

Figs. 3A-3F show alternative exemplary embodiments of a plan view of a content information layer, illustrating the different orientations of the anisotropies of the two phases forming the layer;

Figs. 4A and 4B illustrate different morphologies of the two phases of the content information layer;

Figs. 5A and 5B show respectively a schematic representation of a side chain liquid crystal polymer (SCLCP) and a liquid crystalline diacrylate C3M, as used during a manufacturing method in accordance with an embodiment of the present invention; and

Fig. 6 illustrates a device for scanning an optical record carrier including a content information layer in accordance with an embodiment of the present invention.

Fig. 7 shows a cross-sectional view of a dual-sided optical disc incorporating a content information layer in accordance with another embodiment of the present invention;

Fig. 8 shows a cross-sectional view of a single-sided optical disc incorporating a content information layer in accordance with another embodiment of the present invention.

The present inventors have realized that a content information layer or label layer can be provided that overlies the user information layer on an optical record carrier, but does not interfere with the scanning of the user information layer.

Such a content information layer (or at least portions of the content information layer, termed herein "zones") is arranged to transmit (i.e. not substantially reflect or absorb) a beam of first radiation used to scan the user information layer. These zones are visible, as they are arranged to reflect and/or absorb different, second radiation. As most

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radiation sources (including the sun) emit unpolarized radiation, the zones will appear hazy under ambient light as radiation of at least the second radiation is reflected or absorbed.

Preferably, the zones are arranged to transmit first radiation, but reflect or absorb all other radiation. This increases the visibility of the zones under illumination by second radiation.

By arranging the zones in any desired shape or configuration (e.g. as characters or images), the information indicative of the content of the disc, or the origin of the disc, or identifying the disc, or simply providing a pleasing pattern, can be provided.

In this manner, a content information layer can be placed on a two-sided disc, without preventing the user information layer of the disc being scanned by radiation of the first polarization.

It will be appreciated that such a content information layer may be applied to any optical record carrier including cards and cylindrical media, and is not limited to optical discs. Further, such a content information layer may be provided on a single-sided media e.g. to allow information or patterning to be provided on both sides of the media, thus increasing either the amount of information available to the user, or enhancing the overall appearance of the media.

Figure 1 shows a first embodiment of a record carrier according to the invention. A content information layer is provided at the entrance face 106. Alternatively, the content information layer may be covered by a transparent layer, be embedded in the substrate or be arranged on the user information layer. The content information in the content information layer is represented by zones comprising a material having a high transmission for the radiation used for scanning the user information layer 104. The material has a low transmission for radiation at other wavelengths. Appropriate materials for the zones are dyes, which in general have a strongly wavelength-dependent transmission. Examples of dyes and their color under ambient lighting conditions are:

1,1'-Diethyl-2,2'-carbocyanine Iodide (violet, transparent for CD, DVD)

2-[6-(Diethylamino)-3-(diethylimino)-3H-xanthen-9-yl]benzoic acid (green, transparent for CD, DVD, BD)

2,3,5,6-1H,4H-Tetrahydro-9-(3-pyridyl)-quinolizino-[9,9a,1-gh]coumarin (yellow, transparent for CD, DVD)

2-(p-Dimethylaminostyryl)-pyridylmethyl Iodide (orange, transparent for CD, DVD transparent)

2-(p-Dimethylaminostyryl)-benzothiazolylethyl Iodide (red, transparent for CD, DVD, BD)

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in which
CD is the Compact Disc (first radiation wavelength 780 nm),
DVD is the Digital Versatile Disc (first radiation wavelength 650 nm) and
BD is the Bluray Disc (first radiation wavelength 405 nm).

Since these dyes may be added in very small amounts to the matrix, these dyes do not have a substantial influence on the optical path length. Therefore aberrations in the optical path due to differences in the optical path length caused by the dye are negligible. Furthermore, dyes can be chosen that approach the refractive index of the matrix to a large extent.

Figure 2 shows an optical disc 2 in accordance with another embodiment of the present invention. The content information layer can be a cover layer on a substrate, such as layer 107 in Figure 1 or a layer anywhere in the substrate or a layer arranged directly on the user information layer. In the embodiment of Figure 2, the content information layer replaces the cover layer of the disc and the substrate. In Figure 2 the disc 2 is two-sided, and thus has two separate user information layers 4a and 4b mounted either side of a separation layer or substrate 5. A respective content information layer 3a, 3b overlies each user information layer 4a, 4b. Each user information layer 4a, 4b is scanned by providing a polarized radiation beam incident upon the respective user information layer 4a, 4b through the corresponding entrance face 6a, 6b.

The realization of such a content information layer with zones having dependent-dependent transmission can be accomplished in several ways.

Generally, the layer will consist of a continuous first phase (matrix) and a second phase that has a continuous, co-continuous or, preferably, dispersed character (in the form of small domains). An area of the second phase is a zone and an area of the first phase the medium surrounding the zone. At least one of the two phases is of an anisotropic nature, and exhibits birefringence, such as a liquid crystal (LC). The two phases may be formed of a single material (in different states, or with different orientations), or of two or more separate materials. Possible implementations are schematically depicted in figures 3A to 3F.

Figures 3A-3F show plan views of a content information layer 3 in accordance with different embodiments of the present invention, providing exemplary implementations of the morphology of the polarization dependent scattering zones.

The information content layer 3 in each instance comprises a first phase 43b, which provides a matrix for the particles of the second phase 43a. The arrows or crossed

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circles (43a', 43b') in each figure illustrate the direction of anisotropy of the respective phase.

For instance, in Figure 3A the matrix material forming the first phase 43b has an anisotropy indicated by a crossed circle, thus indicating that the anisotropy extends perpendicular to the plane of the page. In contrast, the second phase 43b has a double-headed arrow extending left to right, and thus indicates that the anisotropy extends across the page. In the figures where two arrows are crossed i.e. 43b' of figure 3E and 43a' of figure 3F, this indicates that the relevant phase is isotropic.

An isotropic material is a material which has properties (in this particular description), refractive index, which do not vary with orientation. An anisotropic material is a material in which the physical properties (in this description, refractive index) depend upon the orientation of the material.

The match or mismatch between the refractive indices of the matrix material and the material of the second phase is significant. This match or mismatch is chosen intentionally, by an adequate choice of the materials used, and can be established a priori or can be realized in-situ after a transformation of the initially used materials, through for instance phase separation, (photo-induced) polymerization, thermal treatment, removal of material, or combinations thereof.

To illustrate this further, consider the example of Figure 3A, where both phases display anisotropy, *e.g.* by using LC molecules in their nematic or smectic phase. The alignment conditions of the two phases are such that the matrix consists of homeotropically oriented LC molecules (indicated by the crossed circle in Figure 3A), whereas the dispersed phase consists of planarly oriented LC molecules with a left-to-right orientation. If the materials are chosen such that the ordinary refractive index of the matrix material matches the ordinary refractive index of the dispersed phase, no effective refractive index mismatch is experienced by the incident laser beam if the state of linear polarization of the incident beam is parallel to the alignment direction of the LC molecules in the dispersed phase. However, the mismatch between the ordinary refractive index of the matrix and the extraordinary refractive index of the dispersed phase results in scattering of this polarization direction. Because the viewer cannot discriminate between different polarization states, the appearance of the film will be hazy in those areas where the condition as shown in Figure 3A is fulfilled. By patterning the cover layer, resulting in for instance areas with orientations as shown in Figure 3A and areas possessing the arrangement as shown in Figure 3B, information can be placed on the cover disc that is visible to the user without affecting the writing and read-out

of the stored information of the underlying layers. Since this principle can be applied to both sides of a two-sided disc, a doubling of the storage capacity can be accomplished, without sacrificing the printing possibilities of a disc (i.e. the information storage capability of the user information layer).

The above described example serves to illustrate the concept. Alternatively, the ordinary refractive index of the matrix phase can be matched to the extraordinary refractive index of the dispersed phase, thus reversing the direction of linear polarization for which the scattering is experienced.

Other alignment configurations are also feasible, as shown in Figures 3C-3F. At least one phase must show anisotropic alignment, but the second phase – whether matrix or dispersed phase – does not necessarily have to be anisotropic. Provided the isotropic refractive index of the isotropic phase is matched to either one of the refractive indices of the anisotropic phase (e.g. Figures 3E and 3F), scattering is still observed, albeit to a lesser degree than will be observed for the arrangement shown in Figure 3A.

Furthermore, the morphology of the dispersed phase is not restricted to droplet-shaped domains (as shown in Figure 4A), but can also have a continuous (*e.g.* interpenetrating networks) or a co-continuous (*e.g.* aggregates, agglomerates) character, as shown schematically in Figure 4B.

Morphologies consisting of a continuous phase (matrix) and a second phase that has a continuous, co-continuous or, preferably, dispersed character (domains) have been described in the literature.

For instance, so-called polymer dispersed liquid crystals (PDLCs) consist of an isotropic or anisotropic polymer matrix and a dispersed liquid crystalline phase (e.g. as shown in Figure 3E) and are, for instance, described in Fergason, J.L., *SID Dig. Tech. Pap.*, 16, 68(1985).

These systems are generally created in-situ, using phase separation techniques. Starting from a homogeneous mixture of monomers and inert liquid crystals, phase separation is either induced thermally (thermally induced phase separation: TIPS), by evaporation of a co-solvent (solvent induced phase separation: SIPS), or by photo-chemical means (polymerization or chemically induced phase separation: PIPS/CIPS).

During the course of these processes, phase separation in polymer-rich and polymer-poor regions will occur, and the final morphology can be accurately tuned, depending on the proper process conditions. The thus obtained dispersed low molecular

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weight LC phase can be post-cured in a preferred alignment – optionally different from that of the matrix – using for instance an electric or a magnetic field.

Other combinations of inert or reactive LCs with polymers have also been described, such as combinations of LCs with flexible polymers, (Fergason, J.L., *SID Dig. Tech. Pap.*, 16, 68 (1985)), side chain liquid crystal polymers, (Coles, H.J., *J. Chem.Soc. Faraday Discuss.*, 79, 201 (1985)), main chain liquid crystal polymers, (Wilderbeek, H., PhD-Thesis, Eindhoven University of Technology, (2001); and Wilderbeek, H.T.A., Van der Meer, M.G.M., Bastiaansen, C.W.M., Broer, D.J., *J. Phys. Chem. B*, 106, 12874 (2002)), (isotropic or anisotropic) network-type structures (Drzaic. P.S., "Liquid Crystal Dispersions", World Scientific, Singapore, 1995, and Hikmet, R.A.M., *J. Appl.Phys.*, 68, 4406 (1990)), or dispersed polymer particles (Van Boxtel, M.C.W., Janssen, R.H.C., Broer, D.J., Wilderbeek, H.T.A., Bastiaansen, C.W.M., *Adv. Mater.*, 12, 753 (2000)). It should be noted that the embodiments of the present invention are not limited to the use of organic (polymeric) phases alone, as inorganic phases can be used as well (Eidenschink, R., De Jeu, W.H., *Electronics Letters*, 27, 1195 (1991)).

It will be appreciated that a variety of materials can be utilized to form the content information layer, with the materials being utilized to form the matrix or the domains or zones. For instance, if desired, the materials forming the matrix and/or the domains or zones can, individually, be substantially transparent to visible radiation. Alternatively, one or more of the materials can appear colored under visible or fluorescent radiation e.g. the material is a dye. Such a colored material can be isotropic or anisotropic. By providing such dyes, content information layers with a colored appearance can be produced.

Decoupling of the fixation of the matrix from that of the dispersed phase can be accomplished using the techniques described above. For instance, an isotropic or anisotropic (*e.g.* side chain liquid crystal polymer, SCLCP) polymeric matrix and a reactive LC is dissolved in a co-solvent, the co-solvent is evaporated resulting in the desired morphology, and the reactive LC phase is fixated in the preferred alignment using photo-induced polymerization.

Alternatively, in a second non-limitative example, an isotropic or anisotropic monomer is mixed with an anisotropic monomer to form a homogeneous phase. Upon polymerization of the first monomer, *e.g.* photo- chemically, phase separation results in the desired morphology. The second monomer is subsequently polymerized thermally. In between these two polymerization steps, reorientation of one or both of the phases can be effected optionally, for instance by external means such as electric or magnetic fields, shear

forces, flow fields or alignment layers. For this purpose, LC materials may be used that possess either a positive or negative dielectric anisotropy ($\Delta\varepsilon$).

'Decoupling-mechanisms' other than the illustrated thermal-photochemical mechanism can also be deployed, such as photo-polymerization at different wavelengths, photo-polymerization using different polarization states, polymerization at different temperatures etc.

Furthermore, also mobilisation-immobilisation strategies can be employed using first or second order phase transitions or glass transition in combination with slow or fast (*e.g.* quenching) heating or cooling.

In all cases, use can be made of additives such as thermal initiators, photo initiators, inhibitors, radical scavengers, chain transfer agents, stabilizers, surfactants, sensitizers, dopants, isotropic or anisotropic (fluorescent) dyes, or combinations thereof.

The preferred initial alignment of anisotropic phases can optionally be realized by using alignment layers (*e.g.* mechanically aligned, photo-chemically induced), surfactants, electric or magnetic fields, shear forces or flow fields. To this end, the cover layer may optionally be sandwiched between transparent electric conductive layers, such as indium tin oxide, that can optionally be coated with said alignment layers.

Based upon the teaching herein, various methods will be apparent to the skilled person to produce the content information layer. Four alternative methods of producing such a layer are now described, in relation to the production of an optical data storage medium such as an optical disc.

Method 1

In this first embodiment, an alignment layer is deposited on the outermost layer having a reflective function, *e.g.* metal, within the optical data storage medium. The alignment direction of the alignment layer is mechanically induced by rubbing the alignment layer in a circular motion. This can be realized by rotation of the substrate when in contact with the device enforcing the alignment, *e.g.* velvet cloth. Subsequently, a spacing layer is applied by deposition of spacers (*e.g.* foils, beads or rods, optionally embedded in an adhesive) on the edges of the disc and/or at different predetermined positions on the disc, which determines the final thickness of the anisotropic layer.

Next, a mixture of a low molecular weight reactive liquid crystal (LC) and a side chain liquid crystal polymer (SCLCP), as indicated schematically in Figure 5A, is deposited on the optical storage medium, overlaying the alignment layer.

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The low molecular weight reactive LC consists of a LC monomer or mixture of monomers with a positive $\Delta\varepsilon$ that upon polymerization will form a cross-linked network, such as an LC diacrylate (*e.g.* C3M in Figure 5B, a multifunctional LC methacrylate), or a multifunctional LC thiol-ene monomer. The side chain liquid crystal polymer will typically consist of a thermotropic polymer with a glass transition preceding one or more enantiotropic LC phases, with transition temperatures below the softening or degradation temperature of the optical data storage mediums substrate. Added to the low molecular weight LC monomer is a photo-initiator, and/or other additives as described herein. The mixture can be deposited as such, *e.g.* as a phase separated mixture, or can be deposited as an isotropic mixture, followed by fast or slow cooling or by evaporation of a co-solvent, in order to establish the desired morphology.

Next, a re-usable substrate provided with either a structured transparent electrode (*e.g.* indium tin oxide, ITO) or a transparent electrode in the shape of the image which will be visible to the customer, is placed on top of this mixture and pressed until this substrate and optical data storage medium are limited in movement due to the spacers. An alignment layer is preferably applied on the transparent electrode. The deposition of the covering electrode may be done preferably before, but also during or after the desired morphology of the LC layer is established. Subsequently, a waiting period, optionally combined with a heating step, may be employed to minimize or eliminate the presence of disclinations within the LC layer.

The low molecular weight LC component is cured using UV-initiation or thermal initiation, as to fixate the prior established morphology or to establish the desired morphology in-situ by induced-induced phase separation. In the latter case, the final morphology is determined by several parameters such as the polymerization kinetics, and can be influenced by for instance changing the exposure conditions (radiation intensity, exposure time) or changing the thermal conditions (temperature, time).

The established uniaxially aligned LC layer, consisting of separate phases with identical refractive indices, is still transparent to both the laser beam and the user. The required local unidirectional refractive index mismatch is induced by applying an electric field over the LC layer and simultaneous heating of the layer to a temperature where the SCLCP exhibits a mesophase, well below the softening or degradation temperature of the medium. The side chain substituents of the SCLCPs will reorient along the electric field lines and establish the refractive index mismatch, which is fixated by slow or fast cooling of the LC layer while maintaining the electric field. Once the new local orientation is established

and the temperature is below the glass transition of the SCLCP the electric field can be removed.

Note that both the electric field and the thermal field may be applied locally, *e.g.* by patterning of the electrodes or by selective addressing of the electrodes, or by using the thermal profile of a focused laser beam. The electric field is applied between the removable upper electrode and the information (metal) layer.

Finally, the substrate with the electrode may optionally be removed and re-used for another substrate to increase reproducibility and reduce costs, and the current data storage medium containing the content information layer may be optionally covered with a protective layer. All of the steps described above can also be performed in parallel to both sides in order to increase the manufacturing speed.

Method 2

Similar to the situation described for Method 1, a mixture of two different reactive liquid crystals having a positive dielectric anisotropy is used, in which the monomers can be polymerized separately and independently. To this end, one LC component can for example consist of monomer that can be polymerized photochemically (*e.g.* cationically using onium salts for epoxides, oxetanes or vinylethers, or Type I or Type II free-radical initiators for acrylates, methacrylates or thiol-enes), whereas the other component consists of a LC monomer that can be polymerized thermally (*e.g.* thermal initiators inducing free-radical polymerization of acrylates, methacrylates, vinyl monomers or thiol-enes).

The induced morphology, for instance obtained by the methods described in the body of this description, is fixated by the selective polymerization of one of the LC monomers (*e.g.* using UV-light), subsequent redirection of the remaining unreacted LC monomer or monomers using an electric field applied via the structured electrodes, and followed by fixation of the unreacted components using a different polymerization mechanism (*e.g.* temperature increase or using light at a second wavelength). Alternatively, the final morphology is obtained during the polymerization of the first LC component or components.

Method 3

Similar to the situation described for Method 2, an alignment layer inducing a homeotropic alignment is used. The low molecular weight LC fraction consists of a LC monomer or mixture of LC monomers with a negative dielectric anisotropy ($\Delta\varepsilon < 0$), in

which the monomers can be polymerized separately and independently. Redirection of the second, not yet fixated phase is effectuated using an electric field upon which the molecules reorient to a planar alignment. The preferred alignment may be optionally enforced using a dopant, protrusions, or structured electrodes inducing in-plane electric fields.

Method 4

In an identical situation as described for Method 3, a (fluorescent) anisotropic dye is dissolved in one or both of the LC monomers or monomer mixtures. After redirection, for example according to the procedure described in Method 3, a contrast visible to the user is induced resulting from the different anisotropic absorption cross sections of the anisotropic dye.

An aspect of the present invention includes devices that are arranged to write content information to the content information layer of an optical record carrier e.g. by changing the second phase to the desired orientation whilst *in situ* upon the recording medium. In such instances, the optical record carrier comprises a material that may be recorded to provide the desired zones. Such a device may also function as a scanning device.

Figure 6 shows a device 1 for scanning an optical record carrier 2 in accordance with an embodiment of the present invention. The record carrier comprises a transparent layer 3, on one side of which an user information layer 4 is arranged. The carrier comprises a content information layer as described above. The content information layer is formed as part of the transparent layer 3. The side of the user information layer facing away from the transparent layer is protected from environmental influences by a protection layer 5. The side of the transparent layer facing the device is called the entrance face 6. The transparent layer 3 acts as a substrate for the record carrier by providing mechanical support for the user information layer.

Alternatively, the transparent layer may have the function of protecting the user information layer, while the mechanical support is provided by a layer on the other side of the user information layer, for instance by the protection layer 5 or by a further user information layer and a transparent layer connected to the user information layer 4.

User information may be stored in the user information layer 4 of the record carrier in the form of optically detectable marks arranged in substantially parallel, concentric or spiral tracks, not indicated in the Figure. The marks may be in any optically readable form, e.g. in the form of pits, or areas with a reflection coefficient or a direction of magnetization different from their surroundings, or a combination of these forms.

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The scanning device 1 comprises a radiation source 11 that can emit a radiation beam 12. The radiation source may be a semiconductor laser. A beam splitter 13 reflects the diverging radiation beam 12 towards a collimator lens 14, which converts the diverging beam 12 into a collimated beam 15. The collimated beam 15 is incident on an objective system 18.

The objective system may comprise one or more lenses and/or a grating. The objective system 18 has an optical axis 19. The objective system 18 changes the beam 17 to a converging beam 20, incident on the entrance face 6 of the record carrier 2. The objective system has a spherical aberration correction adapted for passage of the radiation beam through the thickness of the transparent layer 3. The converging beam 20 forms a spot 21 on the user information layer 4. Radiation reflected by the user information layer 4 forms a diverging beam 22, transformed into a substantially collimated beam 23 by the objective system 18 and subsequently into a converging beam 24 by the collimator lens 14. The beam splitter 13 separates the forward and reflected beams by transmitting at least part of the converging beam 24 towards a detection system 25. The detection system captures the radiation and converts it into electric output signals 26. A signal processor 27 converts these output signals to various other signals.

One of the signals is a user information signal 28, the value of which represents user information read from the user information layer 4. The information signal is processed by an information processing unit for error correction 29. Other signals from the signal processor 27 are the focus error signal and radial error signal 30. The focus error signal represents the axial difference in height between the spot 21 and the user information layer 4. The radial error signal represents the distance in the plane of the user information layer 4 between the spot 21 and the center of a track in the user information layer to be followed by the spot.

The focus error signal and the radial error signal are fed into a servo circuit 31, which converts these signals to servo control signals 32 for controlling a focus actuator and a radial actuator respectively. The actuators are not shown in the Figure. The focus actuator controls the position of the objective system 18 in the focus direction 33, thereby controlling the actual position of the spot 21 such that it coincides substantially with the plane of the user information layer 4. The radial actuator controls the position of the objective lens 18 in a radial direction 34, thereby controlling the radial position of the spot 21 such that it coincides substantially with the central line of track to be followed in the user information layer 4. The tracks in the Figure run in a direction perpendicular to the plane of the Figure.

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The scanning device in this particular embodiment is also adapted to scan a second type of record carrier having a thicker transparent layer than the record carrier 2. The device may use the radiation beam 12 or a radiation beam having a different wavelength for scanning the record carrier of the second type. The NA of this radiation beam may be adapted to the type of record carrier. The spherical aberration compensation of the objective system must be adapted accordingly.

The radiation beam incident upon the optical record carrier 2 has a predetermined polarization. This may be achieved in a number of ways e.g. a polarizer may be placed at any point within the path of the beam. However, in most instances, a laser (e.g. a laser diode) is used as the radiation source 11, with the laser typically producing a linearly polarized radiation beam.

By providing a content information layer as described above, embodiments of the present invention allow such a layer to be applied to one or both sides of a two-sided optical record carrier, without inhibiting the reading of information from the user information layer on the optical record carrier. This allows the ready identification of the carrier and/or the user information stored on the carrier.

Figure 7 shows another embodiment of a record carrier 702 according to the invention. A content information layer 706 is provided at the entrance face of the substrate 703. The content information layer has an area and comprises a plurality of substantially equally spaced and substantially opaque colored subareas 706r, 706g. Appropriate materials for the colored subareas are e.g. strongly colored ink dots, which are wide-spread. The ink dots preferably have a zero or nearly zero optical transmission for the first radiation. Strongly colored dyes with sufficient absorption at the first radiation wavelenght may also be used. Examples of dyes are mentioned in the description of Fig. 1. Said colored subareas 706, 706r, 706g preferably have a size between 75 and 20000 $\mu m^2$. They may be substantially circular or have another shape e.g. square, rectangular or honeycomb. The colored subareas occupy a value selected from 10 to 30 % of the total the content information layer area and are substantially evenly spread over the total the content information layer area. This percentage may be called coverage. In the embodiment of Fig. 7 circular ink dots have a surface area of about 314 $\mu m^2$, corresponding to a radius r of 10 $\mu m$ and are equally spaced 5*r=50 $\mu m$ apart. This results in a coverage of $\pi/5^2$ = 12.5 %. The ink dots have a transmission of zero for the first radiation. Therefore this percentage also represents the optical transmission of the content information layer for the first radiation. Diffraction effects are not taken into account and will be negligible. The height of the ink dots is typically in the order of 5 - 20 $\mu m$, in

thios embodiment about 5 μm. The matrix of ink dots 706 represents a visible image 706g, 706r because not all ink dots have the same color. In the embodiment of Figure 7, the content information layer 706 (and 706 at the opposite side) is deposited on the substrate 703b and 703a. Deposition may be performed by known deposition printing techniques such as tampon, silk screen printing and ink jet printing. In Figure 7 the disc 702 is two-sided, and thus has two separate user information layers 704a and 704b mounted either side of a separation layer or substrate 705. Each user information layer 704a, 704b is scanned by providing a radiation beam incident upon the respective user information layer 704a, 704b through the corresponding content information layers 706.

In Figure 8 another embodiment of an optical record carrier according to the invention is shown, wherein the content information layer 806 comprises a plurality of differently colored sublayers 806g, 806r, 806p, 806b and 806y substantially equally transparent for the first radiation. The thickness of the colored sublayers is typically about 2 μm. The colored sublayers represent a visual image, e.g. a label. The user information layer 804 is scanned by providing the beam 810 of first radiation incident upon the user information layer 804 through the content information layer 806. The content information 806 layer has a substantially uniform optical thickness at the first radiation wavelength in order not to disturb reading and writing of information from or onto the user information layer 804 of the optical record carrier at the first radiation wavelength. This is achieved by the presence of a substantially optically transparent and flat cover layer 806t facing away from the user information layer 804. The cover layer is thick enough to achieve a flat top surface, i.e. levelling out the differences and the gaps between the colored subareas. The total thickness of the colored subareas and the cover layer may e.g. be 2 - 3 μm, but other thicknesses are not excluded. Further layers 805 are present for protection of the user information layer 804. The further layers 805 may also comprise the other half of a dual-sided disc including a second content information layer according to the invention (compare Fig. 7 reference numeral 706). The sublayers 806g – 806y are colored and deposited according to the desired visual image by known printing techniques. The transparent coverlayer 806t may be deposited by e.g. spincoating.